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Trespasser Detection on Railroad Property Using Unmanned Aerial Vehicles

DOT/FRA/ORD-20/33

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14. ABSTRACT
The U.S. Department of Transportation's (DOT) John A. Volpe National Transportation Systems Center (Volpe), under the direction of DOT's Federal Railroad Administration (FRA) Office of Research, Development and Technology (RD&T), conducted a research study that evaluated the effectiveness of using an unmanned aerial vehicle (UAV) to detect trespassers on railroad property. The team cooperated with the Brunswick, Maine Police Department (BPD), which agreed to be trained in operating and maintaining the UAV, and to perform periodic overflights of the railroad property in Brunswick. Over the course of twelve months, BPD conducted 32 flights over railroad property, but was unable to discover trespassing events in progress. The researchers concluded that certain types of trespassing, which occurs frequently but in short duration, were more difficult to detect using a UAV than trespassing that involves loitering on the right-of-way. However, the UAV made it easier for BPD to patrol remote, hard-to-reach sections of track.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

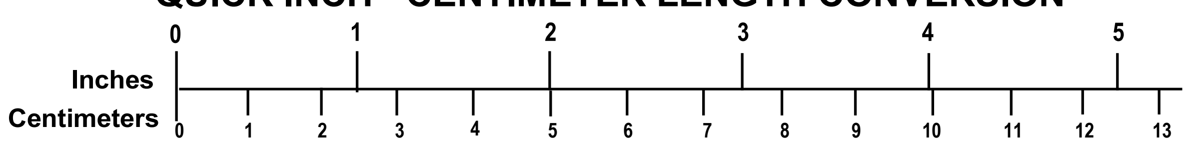
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

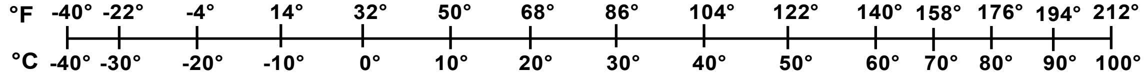
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures.
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The U.S. Department of Transportation, Federal Railroad Administration (FRA) Office of Research, Development, and Technology (RD&T) sponsored the work leading to this report. The authors would like to thank Sam Alibrahim, Division Chief, RD&T Train Control and Communications Division; Francesco Bedini Jacobini, Program Manager, RD&T Train Control and Communications Division; and Tarek Omar, Michail Grizkewitsch, and Norma Griffiths of FRA for their guidance during various phases of the project.

The authors would like to thank the Brunswick Police Department (BPD), in particular Commander Thomas Garrepy and Arthur Frizzle, for their extensive support in safeguarding and maintaining the equipment, and to the BPD officers who underwent the training to operate the drone and conduct the flights. The authors would also like to thank the Town Council of the Town of Brunswick for granting permission to perform this test.

Contents

Illustrations

Executive Summary

The John A. Volpe National Transportation Systems Center (Volpe) was tasked by the Federal Railroad Administration (FRA) Office of Research, Development and Technology (RD&T) with studying the potential for using unmanned aerial vehicles (UAVs, or “drones”) for detecting trespassers on railroad property. Volpe partnered with the Brunswick, Maine Police Department (BPD) to become trained UAV pilots, to operate and maintain the drone, and to periodically overfly local railroad property in an attempt to detect trespassers.

The primary objective of this project was to select and field-test a UAV system to determine if the hardware could function reliably and if police officers could be trained to use the equipment effectively. To this end, Volpe researchers found the equipment functioned as expected, and the officers had little difficulty learning to safely and legally operate the aircraft. However, Federal Aviation Administration limitations restricting UAV operation to line-of-sight limited the distance that the drone could be flown, especially in the heavily forested area of coastal Maine. Although railroad trespassing occurs frequently in Brunswick, trespassers tend not to dwell on the tracks in this area, making detecting them with a drone (which is only airborne for a few minutes at a time) a rare coincidence. However, BPD indicated that the drone made it much easier for them to see some sections of the track that are located in remote, hard-to-reach locations that otherwise wouldn’t have been patrolled due to the time and effort involved.

Volpe recommends that police departments in rail trespass hotspots explore the use of this technology for trespass detection and mitigation. In some cases, this tool may already be available to police for other purposes, and its use for trespass should be considered.

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe) provides technical support to the Federal Railroad Administration (FRA) on grade crossing safety and trespass prevention research. This support includes key research associated with railroad rights-of-way (ROW), including highway-rail intersection (HRI) and trespass issues.

In 2018, there were 841 rail-related fatalities in the United States.[1] Of these, 541 resulted from trespassing incidents[2], and 255 of these were determined to be suicides.[3] With the preponderance of railroad fatalities in the US each year involving trespassing activity, FRA is evaluating approaches aimed at addressing this problem.

In 2013, the FRA Office of Research, Development, and Technology (RD&T) tasked Volpe with developing and evaluating a system to detect trespassers on a railroad ROW. Preliminary research using temporary cameras at selected locations in and around Brunswick, Maine showed that several sites averaged multiple trespassing events per day. In 2018, after recognizing the limitations of fixed camera sites in detecting trespassers, FRA requested that Volpe look into the efficacy of using an unmanned aerial vehicle (UAV, or "drone") to actively search for trespassers. This effort was broken out into a separate research effort by the Volpe research team.

1.1 Background

This report details Volpe's findings in assessing various aspects of using a UAV to detect trespassers on a railroad ROW. This project builds off the lessons learned in fixed-site trespasser detection systems deployed by FRA and Volpe in Pittsford, New York and Brunswick. Through the latter project, Volpe has an existing relationship with the Brunswick Police Department (BPD), and there is a known pattern of railroad trespassing, so Volpe and the FRA decided to partner with them in this effort.

1.1.1 Test Site

Volpe and FRA identified Brunswick as a test location for this project. Brunswick is one endpoint for the Amtrak *Downeaster;* the other is Boston's North Station. Amtrak currently runs five round-trips per day, and in 2017 established a layover facility in Brunswick. Freight rail on the same line is operated by Pan Am Railways, which is responsible for maintaining the tracks, signals, and grade crossing safety equipment. The railroad property within Brunswick is owned by the Maine Department of Transportation, and a spur that crosses Jordan Avenue is maintained by Central Maine and Quebec Railway. A map of Brunswick, Maine is shown in Figure 1. The rail lines are shown in black, and the areas of interest to this project are noted.

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[1] Obtained from the FRA Office of Safety Analysis website: https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/CasualitiesReport.aspx on August 30, 2019.

[2] Obtained from the FRA Office of Safety Analysis website: https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/castally4.aspx on August 30, 2019.

[3] Obtained from the FRA Office of Safety Analysis website: https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/suiabbr.aspx on August 30, 2019.

Figure 1 – Aerial map of Brunswick, Maine Source: Google Earth

Brunswick, Maine is located on the Maine seacoast about 25 miles northeast of Portland, Maine and 130 miles north of Boston. Brunswick is home to Bowdoin College, so there is a large number of students living in the area.

The Federal Aviation Administration (FAA) has established no UAV flight restrictions in Brunswick within the 400 feet or less of altitude used by BPD during this test. There is an uncontrolled airport nearby (Brunswick Executive Airport) on the former site of the Brunswick Naval Air Station. Because it is uncontrolled, it is entirely the responsibility of the UAV pilot to remain clear of any low-flying aircraft, and so its existence did not inhibit the use of the drone during this study.

1.1.2 Past Research

Volpe conducted two previous tests of trespasser detection systems, one beginning in 1999 in Pittsford and one beginning in 2013 in Brunswick. The findings of the Pittsford study are in the report, Railroad Infrastructure Trespassing Detection System Research in Pittsford, New York[4]. The findings of the Brunswick study can be retrieved at (*Insert link here*).

Some railroads have extensive UAV programs already in place. BNSF uses large, fixed-wing drones to perform rail inspections. Earlier this year, BNSF received an FAA exemption, enabling

[4] Marco P. DaSilva, William Baron, and Anya Carroll, "Railroad Trespassing Detection Systems Research in Pittsford, New York" (DOT/FRA/ORD-06/03) (Washington, DC: Federal Railroad Administration, 2006), available at https://rosap.ntl.bts.gov/view/dot/8901.

it to perform beyond visual line-of-sight (BVLOS) flights over long stretches of rail infrastructure.[5]

Commuter railroads and transit agencies are also experimenting with drones to patrol their tracks. Tri-Rail[6] and SEPTA[7] are two of the agencies testing them for trespasser detection.

1.2 Objectives

The objectives of this research included:

- Identifying what UAV technology is best suited for detecting trespassers
- Procuring a suite of equipment to be used in aerial detection of trespassers
- Providing training to officers in how to safely and lawfully operate the UAV
- Capturing and analyzing the flight log information about all the aerial trespasser detection missions

1.3 Overall Approach

The foundations for this project began in 2013, when Volpe established a relationship with the BPD to develop and deploy a prototype trespasser detection system. Volpe set up test cameras at selected locations and determined which ones most frequently had trespassing events. After deploying the fixed camera system in 2016 and operating this system for over a year, some of its limitations became clear. One of these was that while the camera sites were in fixed locations, trespassers moved well beyond the cameras' view. FRA suggested investigating the potential for using a drone to actively search for trespassers.

There were several activities that went into conducting this project, including:

- **Identifying UAV Equipment –** The Maine State Police (MSP) had been using a UAV for many months to perform accident reconstruction.[8] BPD suggested that it might be advisable to acquire a similar platform since they could rely on MSP to provide experience and perhaps share equipment in the event of component failures or malfunction. Also, their equipment had the capacity for changing cameras, and could use a thermal imagery camera for detection of trespassers in complete darkness. For these reasons, Volpe settled on the DJI Matrice 200 as the UAV platform.
- **Procuring Components –** Volpe issued a competitive Request for Quotation (RFQ) for the following components:
    - DJI Matrice 200 UAV

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[5] Vesna Brajkovic, "BNSF receives FAA exemption for advance drone operations." *Progressive Railroading*, April 12, 2019.

[6] Marcia Heroux Pounds, "Tri-Rail has new drones to watch the railways for safety. When will they start flying?" *South Florida Sun Sentinel*, March 8, 2019.

[7] Susan Bregman, "SEPTA uses drones to patrol tracks." *The Transit Wire*, November 28, 2017.

[8] Danielle Waugh, "Maine State Police Say New Drones Help With Crashes, Explosions." *New England Cable News*, November 28, 2017.

- Zenmuse X4s daylight camera
- Zenmuse FLIR XT night vision camera
- Spare TB55 batteries and charger
- GPC M200 hard case

In addition to these components, Volpe acquired the following in the same procurements:

- Pix4d Mapper software (for reconstructing rail accidents and for use in future FRA work)
- Onsite pilot training (for preparation in completing the FAA Part 107 Remote Pilot test)
- Onsite training in the use of Pix4d software

Volpe completed this acquisition, and training was provided in Brunswick and Bowdoinham, Maine in September 2018. Figure 2 shows the UAV operated by the BPD during a training flight. Shortly thereafter, BPD launched its first trespass detection flights. In April 2019, BPD received its daytime waiver from FAA, allowing it to fly the drone at night.

Figure 2 – DJI Matrice 200 being operated by Brunswick PD

1.4 Scope

This study investigated various aspects of using a UAV by trained police officers to detect trespassers on a railroad ROW. While the study also notes other potential uses BPD may have for the drone, these ancillary benefits are not the focus of this study.

1.5 Organization of the Report

This report is organized as follows:

- Section 2 describes the selected UAV and the hardware and software components of the system.
- Section 3 presents the conclusion of the study.
- Section 4 lists the references used in this report.

2. Unmanned Aerial Vehicle

Volpe procured a DJI Matrice 200[9] drone for this project. As previously noted, Volpe selected this drone for several reasons, including the existing use of this model by the MSP and its ability to use different camera types. The system came with a controller, battery, and charger. Volpe also procured a Zenmuse X4S daylight camera, a Zenmuse FLIR XT night vision camera, four additional TB55 batteries, a GPC M200 hard case, a DJI Crystal Sky high brightness display, and a perpetual license for Pix4D Mapper Software.[10] Figure 3 shows the UAV kit as delivered by Volpe to BPD.

2.1 Training

Volpe also procured 4 days of onsite pilot training in Bowdoinham and 2 days of onsite Pix4D training at BPD. Volpe also procured a high-performance laptop for operating the Pix4D software.

Figure 3 – UAV kit as delivered by Volpe

[9] https://www.dji.com/matrice-200-series

[10] https://www.pix4d.com

Volpe delivered the drone components and the laptop prior to the pilot training. The pilot training was provided by Flymotion of Tampa, Florida and was provided the week of September 4, 2018. Figure 4 shows a snapshot of the hands-on classroom training provided to BPD. The Pix4D training was provided the following week, by a representative of Pix4D.

Figure 4 – Drone pilot classroom training in Bowdoinham, Maine

All of the DJI devices (the aircraft, display, and even the batteries) require regular software updates through DJI. Periodically, BPD reported the drone would not fly until the update was performed, and on one occasion, the drone aborted a mission in mid-flight and returned to the landing spot because it required an update. As the project progressed, these types of actions became less frequent.

The Matrice 200 has 20 proximity sensors which alert the pilot when obstacles are detected. While pilots are discouraged from flying it in high winds and rain, the Matrice 200 is among the most weather-resistant drones on the market, able to resist winds up to 12 meters per second (26.8 mph).

BPD began flying training missions immediately, and used some of its officers as trespasser targets to better understand how easy or challenging detecting trespassers could be under various conditions. A photo taken from the UAV during this training is shown in Figure 5, and Figure 8 shows the UAV test team at the Brunswick Amtrak layover facility.

Figure 5 – BPD officer as seen from drone during training

Over time, each of the BPD drone operators and two Volpe researchers received their FAA Remote Pilot license. In March 2019, BPD also received their daytime waiver from the FAA, enabling them to operate the drone after dark. The Matrice 200 was not equipped with LEDs for night operations, so Volpe purchased aftermarket lights for this purpose. As shown in Figure 6, the FLIR camera made it much easier to detect people (and animals, as shown in Figure 7) after dark, but researchers found that the thick tree canopies in Brunswick nonetheless obstructed their view using either camera and in all lighting conditions.

Figure 6 – DJI flight controller using the Zenmuse FLIR XT camera

Figure 7 - Thermal image of a deer taken during training using the Zenmuse FLIR XT camera

2.2 Limitations

FAA requires remote pilots to have visual contact with the UAV at all times while in flight. With most of the rail infrastructure in the Brunswick area being in heavily forested areas, there are only a few locations where a UAV can be flown a significant distance while remaining within view of the remote pilot. BPD often used these locations, but it was found that the practical range of most flight operations was only a few hundred yards.

The battery life of the Matrice 200 was typically about 30 minutes of flight time – far longer than the time needed to fly above the tracks to the limits of the pilot's line-of-sight in both directions. In addition, the equipment suite included a replacement set of batteries which can be quickly changed if a flight exceeds this time. High winds can slightly reduce flight time, and pilots are not supposed to fly the Matrice 200 when the winds exceed 30 mph because a loss of control can result. Also, FAA rules prohibit the flight of a UAV over crowds of people, which can be an issue in some cases.

2.3 Authorization for Use

Before it could be legally flown by BPD, the drone needed to be registered with FAA, and the $5 registration fee had to be paid. BPD also established a UAV policy[11], which included the requirement that all pilots obtain their FAA Remote Pilot license. Maine State Law 25 M.R.S. §4501, signed into law in 2015, sets forth several constraints on the use of UAVs by state law enforcement agencies, including "The acquisition of an unmanned aerial vehicle by a law enforcement agency must be approved by the governing body of the governmental unit overseeing the law enforcement agency seeking to make such an acquisition or, in the case of a state agency, by the commissioner of that agency."[12] This meant that BPD first needed to receive approval by the Brunswick Town Council before proceeding with this project. Volpe supported BPD in making this request at a town meeting on November 20, 2017, and the Town Council voted in favor of allowing BPD to acquire and operate the drone.[13] Shortly thereafter, Volpe proceeded with the acquisition of the drone and associated training and software.

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[11] Chris Chase, "Brunswick Council Gets First Look at Police Policy on Drone Use." *Portland Press Herald,* January 16, 2018.

[12] Maine Revised Statutes, Maine Legislature: https://legislature.maine.gov/statutes/25/title25sec4501.html.

[13] Matt Byrne, "Brunswick police could be 1st in U.S. to use drones to spot railroad trespassers." *Portland Press Herald*, December 5, 2017.

Figure 8 – Brunswick UAV test team at Amtrak Layover Facility

2.4 Trespass Detection Flights

The 12-month test period began in October 2018, but overflights of the tracks in the area weren't performed on a regular basis until March 2019, when the weather improved and more pilots had obtained their FAA licenses. To keep records of their UAV activity, BPD began the project by attempting to use the DJI Pilot utility, which provides flight logs and the ability to livestream video from the drone. Unfortunately, BPD could not get the program to recognize them as the owners/operators of the drone, and could not gain consistent access to the flight logs. They also could not get adequate support from DJI. As a result, BPD began using the drone logbook from SafetyDrone[14], a product geared toward first responders. This utility not only collects vital information such as date, time, location of launch, mission type, and pilot, it also captures Google Earth KML data of the drone's flight path in three dimensions. This saved greatly in the need to describe exactly what was flown over. An example of the KML data from a flight that launched from Jordan Avenue on March 8, 2019 is shown in Figure 9.

[14] https://www.safetydrone.org

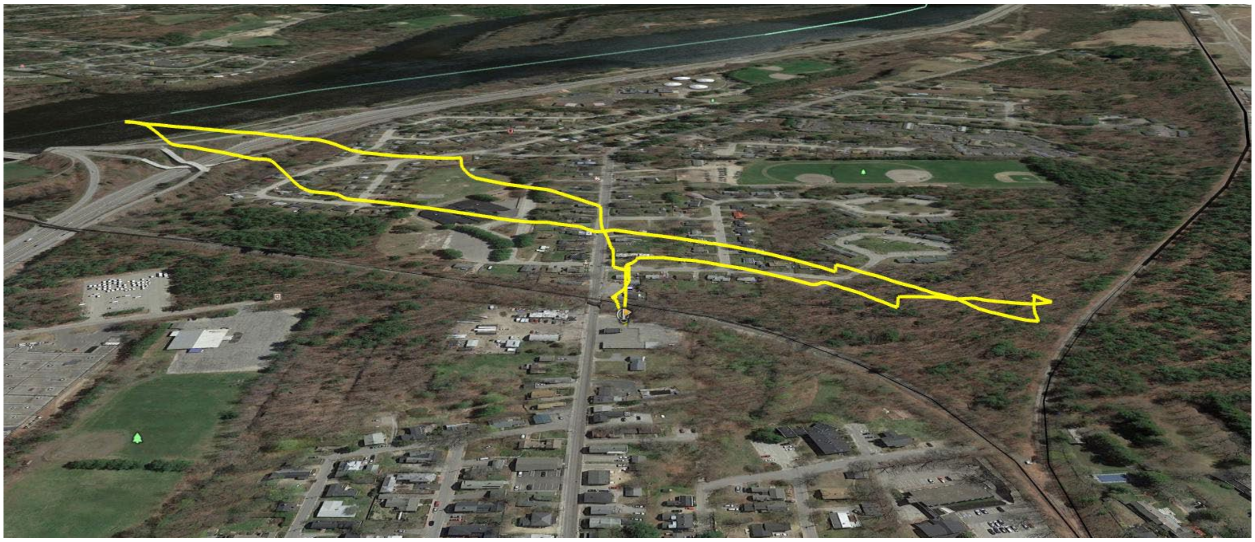
Source: Google Earth

Figure 9 – Example of KML data provided by the SafetyDrone application

BPD also found an alternate method for live streaming video from the drone when needed. In total, BPD conducted 32 railroad overflights during the 12-month test period. It was not unexpected to the researchers that no trespassers were detected during the testing, because rail trespassing in Brunswick tends to be transitory in nature, with most trespassers only being present on the tracks for a few seconds or minutes at a time. Note that the UAV flights were conducted by BPD officers in instances where their duties allowed for the time required to perform trespass detection flights. Since their availability varied throughout the course of the test period, Volpe and FRA had no control over how frequently or for how long such flights were conducted.

In short, although there were some technical challenges early in the study, the UAV equipment and software functioned effectively for BPD and provided all of the functionality they were anticipating for trespasser detection and other law enforcement activities.

2.5 Analysis

Volpe conducts trespass detection projects in a variety of environments throughout the country. In reviewing video of trespassers, Volpe notes that trespassers generally fall into one of three categories:

Category 1: Loitering – Trespassers in this category tend to dwell on or near the tracks. This includes those who use the right-of-way as a quiet place to consume alcohol or drugs, children at play, and homeless people who sleep in the vicinity of the right-of-way.

Category 2: Traversing – This category includes trespassers who walk, run, or ride along or across the right of way while traveling from one place to another. Some use the tracks as a shortcut, while other cross tracks to get to a destination on the other side.

Category 3: Lurking – This category includes people who wait (usually off the right-of-way) for a train to approach, at which time they come onto the tracks. People who commit suicide are in this category.

As noted in Section 1.1.2, Volpe has been studying trespassing in Brunswick since 2013. It turns out that the vast majority of railroad trespassers in Brunswick fall into Category 2. Almost everyone seen on video trespassing on rights-of-way in and around Brunswick walk along or across the tracks, and are present in any one location for only a short period of time. Detecting these types of trespassers using a drone is particularly difficult, because the drone can only fly over a particular location for a few minutes at a time. Clearly, the drone would be much more effective in detecting trespassers in Category 1 and possibly Category 3.

It should also be noted that much of the trackage in Brunswick is located in remote, hard-to-reach locations. BPD indicated that the drone made it much easier for them to see some sections of the track, and enabled them to patrol areas they otherwise wouldn't due to the time involved in reaching the sites.

2.5.1 Ancillary Benefits of the UAV

BPD also was provided a license for Pix4d, which enables them to create accident reconstruction maps from drone imagery. BPD found this capability was helpful in creating forensic maps used to reconstruct any type of accident, including those not involving a train, because it is much less arduous than their previous process.

BPD found there were other law enforcement activities that were greatly facilitated because they had access to a drone. For instance, BPD is responsible for enforcing certain shellfishing regulations. The drone enabled them to quickly see where shellfishing was taking place and determine if it was compliant. They were also able to overfly other law enforcement activities and large events. Finally, while they did not have an incident during the test period, BPD noted that the drone will be a valuable tool in search-and-rescue efforts.

3. Conclusion

This project was primarily a test of the UAV platform to determine if police officers can be easily trained on its use and to determine if the platform functions reliably and effectively as a trespass detection tool. In general, the UAV system and accessories purchased for this project functioned properly as expected. There were a few exceptions early in the project where software updates in the aircraft, controller or batteries were required before the drone would allow itself to be flown. There was also a problem with the DJI Pilot software, which was supposed to create flight logs and allow for streaming video from the drone. Instead, BPD used a product from SafetyDrone which worked much better. Since March 2019, the aircraft, batteries, chargers, and other accessories all worked as expected, and the officers encountered no significant difficulty in learning to fly the aircraft or in passing the FAA test required to obtain a remote pilot's license.

While BPD did not detect trespassers during the test period, this result was not entirely unexpected. Although fixed camera data shows that railroad trespassing occurs almost every day in Brunswick, it does not occur all the time. In Volpe's prior studies of trespassing in the Brunswick area, it was found that trespassers tended not to loiter on or near the tracks; instead, they typically walked along or across them. This made trespassers difficult to detect using periodic drone flights, with operators finding it to be unusual to have a drone in the air at the same time and place that a trespassing event was occurring. Given the FAA line-of-sight requirements for drone operation and the limited sight distance of pilots in the heavily-forested Brunswick area, drone-based surveillance of railroad property did not lead to detection of trespassers. However, BPD found that the drone made it much easier for them to see sections of the track in remote, hard-to-reach areas, enabling them to patrol areas they otherwise wouldn't due to the time involved in reaching the sites. It should be noted that BPD continued to utilize the UAV system well after the evaluation period has ended.

It is possible that drone-based trespasser detection may be more effective if used in places where there are fewer trees, so that the drone can be flown further from the launch site and trespassers are more easily seen from above. Also, drones may be more effective in places where railroad trespassers tend to loiter on or near the tracks for longer periods of time.

Volpe recommends that police departments in rail trespass hotspots explore the use of this technology for trespass detection and mitigation. In some cases, this tool may already be available to police for other purposes and its use for trespass detection should be considered. Volpe hopes FRA will develop this tool for rail trespass applications, and specifically how to coordinate with railroads for its deployment.

4. References

Brajkovic, V. (2019, April 12). BNSF receives FAA exemption for advance drone operations. *Progressive Railroading*.

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Abbreviations and Acronyms

BPD	Brunswick Police Department
BVLOS	Beyond Visual Line-of-Sight
FAA	Federal Aviation Administration
FLIR	Forward-Looking Infrared
FRA	Federal Railroad Administration
HRI	Highway-Rail Intersection
KML	Keyhole Markup Language
LEDs	Light-Emitting Diodes
mph	Miles Per Hour
MSP	Maine State Police
RD&T	Railroad Development and Technology
RFQ	Request for Quotation
ROW	Right-of-Way
SEPTA	Southeastern Pennsylvania Transit Authority
UAV	Unmanned Aerial Vehicle
U.S. DOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems